USE OF *EXTINGUISH PLUS*^{TM} TO REDUCE RED IMPORTED FIRE ANTS AND INCREASE NORTHERN BOBWHITE ABUNDANCE

A Thesis

by

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Submitted to the Office of Graduate and Professional Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

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August 2015

Major Subject: Wildlife and Fisheries Sciences

ABSTRACT

Populations of northern bobwhite (*Colinus virginianus*) have been declining throughout Texas since at least the 1970s. The red imported fire ant (RIFA, *Solenopsis invicta*) was introduced to the southern United States from South America around the 1920s and reached Texas by the 1950s. Previous studies have documented the negative effects of RIFA on northern bobwhite populations through both direct predation and indirect reduction of small invertebrates; a major food source for bobwhites.

In 2013 and 2014, large areas of the Attwater Prairie Chicken National Wildlife Refuge (APCNWR) in Colorado County, Texas were aerially treated with *Extinguish Plus™*, a chemical pesticide and reproductive inhibitor which targets ants. My study took place on this refuge and my objectives included evaluation of the impacts of (1) RIFA treatment on RIFA abundance, (2) RIFA treatment on invertebrate abundance, (3) RIFA treatment on northern bobwhite nest success, and (4) invertebrate abundance on northern bobwhite brood survival. I trapped, banded, and radio-collared northern bobwhites in areas treated and not treated with *Extinguish Plus™* from May 2014 through May 2015. I also collected RIFA and invertebrate abundance data on areas treated and not treated during the 2014 and 2015 northern bobwhite nesting seasons. These data allowed for the assessment of northern bobwhite brood survival, RIFA abundance, and invertebrate abundance across treated and non-treated areas of the refuge.

Treatment with *Extinguish Plus*^{TM} reduced the presence of RIFA on the refuge. However, significantly (P = 0.019) lower mean invertebrate biomass per sample was found in treated areas and no significant (P = 0.219) difference in mean numbers of individuals per sample were found between treated and non-treated areas. Additionally, data collected suggested that non-treated areas had higher bobwhite brood survival than did treated areas.

My data suggest that treatment with *Extinguish Plus*^{TM} did not increase northern bobwhite abundance on the APCNWR during the 2014 nesting season. My results differ from previous studies and this may be due to time since treatment and differences in environmental factors between treated and non-treated areas. It also is possible that northern bobwhites are adapting to the presence of RIFA.

DEDICATION

I dedicate this thesis to my family and friends who always supported and encouraged me throughout my academic experience. Particularly, I dedicate this work to my loving parents, Kevin and Karen Caldwell, and girlfriend, Danielle San Miguel, who kept me going with their unwavering love and inspiration. I also dedicate this work to Jim Alexander, who kindled my interest in quail, quail hunting, and quail management. Thank you all for helping me achieve my goals in a field which I love.

ACKNOWLEDGMENTS

A number of great people helped with and contributed to this project. I would like to thank Dr. Jim Cathey for selecting my project for funding. Funding was provided through the Reversing the Quail Decline in Texas Initiative and the Upland Game Bird Stamp Fund based on a collaborative effort between Texas Parks and Wildlife Department and Texas A&M AgriLife Extension Service.

I would like to thank my committee member, Dr. Mike Morrow, and the rest of the staff (interns included) of Attwater Prairie Chicken National Wildlife Refuge. You all were willing to help this project succeed in any way you could, which included dodging the quail traps that were placed in the roads and otherwise working around us as we conducted our research. Thanks as well to the project interns, Corey Pursell and Jacob Lampman, and post-doc, Dr. Therese Catanach, for their laborious contributions.

I also would like to thank my faculty committee members, Dr. Fred Smeins and Dr. Roel Lopez, for providing guidance and encouragement throughout the project. Lastly, I have to thank Dr. Nova Silvy for his tremendous support, time and effort invested, and commitment to helping me accomplish my goals as a graduate student. His help and guidance were invaluable throughout the study. Dr. Silvy even adopted my cat and didn't fire me when she popped out 5 kittens in his laundry room. He always ensured that I was well fed on field research days. Dr. Silvy, I owe you a strawberry cream pie or 100. Thanks for making my last years at Texas A&M University fun and successful.

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CHAPTER I

INTRODUCTION

Northern bobwhite (*Colinus virginianus*) numbers have been on the decline throughout Texas since at least the 1970s (Bridges et al. 2001). Red imported fire ants (RIFA, *Solenopsis invicta*) were introduced to the United States from South America at Mobile, Alabama around the 1920s (Drees and Vinson 1993). RIFA began a steady spread through the southern United States, reached Texas in the 1950s, and spanned the state by 2013 (Figs. 1.1 and 1.2.).

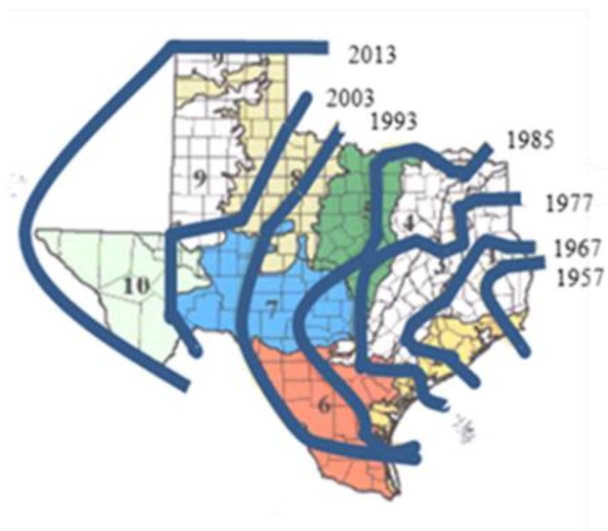


Fig. 1.1. The spread of red imported fire ants in Texas (Drees and Vinson 1993, N. Silvy personal communication).

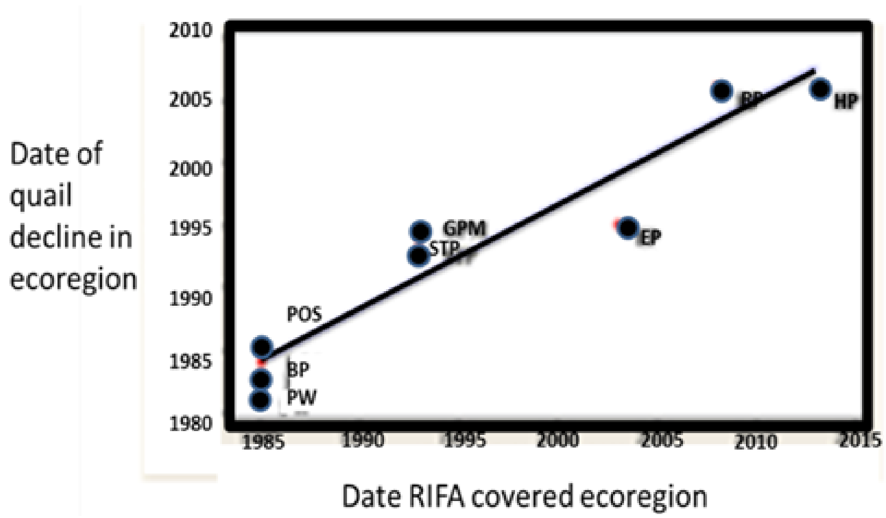


Fig. 1.2. Spread of red imported fire ants by date of quail decline across ecoregions. (PW = Pinywoods, BP = Blackland Prairies, POS = Postoak Savannas, STP = South Texas Plains, GPM = Gulf Coast Prairies and Marshes, EP= Edwards Plateau, RP = Rolling Plains, and HP = High Plains) of Texas (TPWD.texas.gov).

A number of studies have reported that RIFA will prey on young birds, including bobwhites (Drees 1994, Campomizzi et al. 2009, Allen et al. 1995, Mueller et al. 1999). RIFA are known to kill both hatchling bobwhite chicks and older chicks (Mueller et al. 1999). In experimental trials, captive-reared bobwhites spent time and effort responding to RIFA exposure which decreased their time and effort devoted to other activities, thereby reducing fitness (Pedersen et al. 1996). According to Giuliano et al. (1996) bobwhite chicks experienced reduced survival when exposed to as few as 50 RIFA for 60 seconds compared to chicks not exposed to RIFA. RIFA are known to negatively impact bobwhites by preying on invertebrates, which are a major food source for bobwhites (Savory 1989, Wojcik et al. 2001). Porter and Savignano (1990) found that arthropods were reduced by 75% following RIFA invasion. If a lack of small insects and other invertebrates exists to feed young bobwhite chicks, malnutrition and death may follow hatching. Morrow et al. (2015) documented the importance of invertebrate abundance to a sympatric Galliform species: the Attwater's prairie-chicken (*Tympanuchus cupido attwateri*). They concluded that strong invertebrate populations are essential to Attwater's brood survival, and to the long-term recovery of this critically endangered species. They also documented that RIFA had a clear negative impact on invertebrates during their study.

The decline of bobwhites has been concurrent with the westward spread of RIFA (Allen et al. 1995). This correlation may represent a long-term negative impact through direct predation and/or indirectly through insect reduction. Chemical reduction of RIFA may contribute to the recovery of bobwhite populations (Allen et al. 1995, Mueller et al. 1999).

RESEARCH OBJECTIVES

The research objectives of this study were to evaluate the effects of: (1) RIFA treatment on RIFA abundance, (2) RIFA treatment on invertebrate abundance, (3) RIFA treatment on northern bobwhite nest success, and (4) invertebrate abundance on northern bobwhite brood survival. Three chapters in this thesis address these objectives. The following chapters are: (1) Effects of RIFA treatment on RIFA and invertebrate abundance, (2) Influence of RIFA treatment and invertebrate abundance on northern bobwhite nest success and brood survival, (3) Conclusions and management implications. Chapters were prepared as independent papers and contain a degree of repetition in material presented.

STUDY AREA

Research was conducted on the 4,265-ha Attwater Prairie Chicken National Wildlife Refuge (APCNWR) which is located approximately 97 km west of Houston, Texas in Colorado and Austin counties. The APCNWR is dedicated to management of the critically endangered Attwater's prairie-chicken (*Tympanuchus cupido attwateri*). According to Lockwood (1998), the refuge is located on the border between the Gulf Prairies and Marshes and the Post Oak Savannah Ecoregions. In Columbus, Texas (16 km west of the refuge) rainfall (Fig. 1.3) totaled 105.2 cm in 2014; of which 33.55 cm fell in May (www.ncdc.noaa.gov). The highest rainfall recorded in a 24-hour period during May 2014 was 21.08 cm (www.ncdc.noaa.gov). The refuge is bordered primarily by agricultural fields and properties infested with woody vegetation (Lockwood 1998). Common range sites on the refuge include loamy prairie, coarse sand, and claypan prairie (APCNWR soil map, Fig. 1.4). Habitat management practices such as burning, grazing, herbicide treatment, and predator control are used (Lockwood 1998).

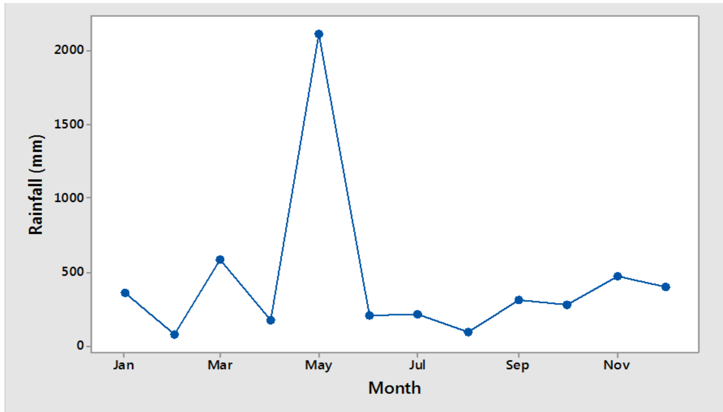


Fig. 1.3. Columbus, Texas rainfall by month in 2014, 16 km West of Attwater Prairie Chicken National Wildlife Refuge in Colorado and Austin counties, Texas.

In October 2013 and again in September–October 2014, portions of the APCNWR were aerially treated with *Extinguish Plus*^{TM} (Wellmark International, Schaumburg, Illinois), a chemical pesticide and reproductive inhibitor that targets ants (APCNWR map, Fig. 1.5). *Extinguish Plus*^{TM}, approved for rangelands in 2007, contains both an adulticide (Hydramethylnon) and an insect growth regulator (IGR) (S-Methoprene), which allows for the sterilization of queens and the killing of worker ants (Extinguishfireants.com). According to the manufacturer's website, *Extinguish Plus*^{TM} is known to be toxic only to ants and fish. The bait is taken up quickly by ants, is slow to act, and requires 3–6 months to take full effect when applied in the fall (Nester 2013). While all ants are susceptible to this product, fire ants dominate bait products like *Extinguish Plus*^{TM} due to their aggressive foraging behavior (Calixto et al. 2007). According to Nester (2013), full effect of the product varies with reinvasion pressure; however, one application per year is usually

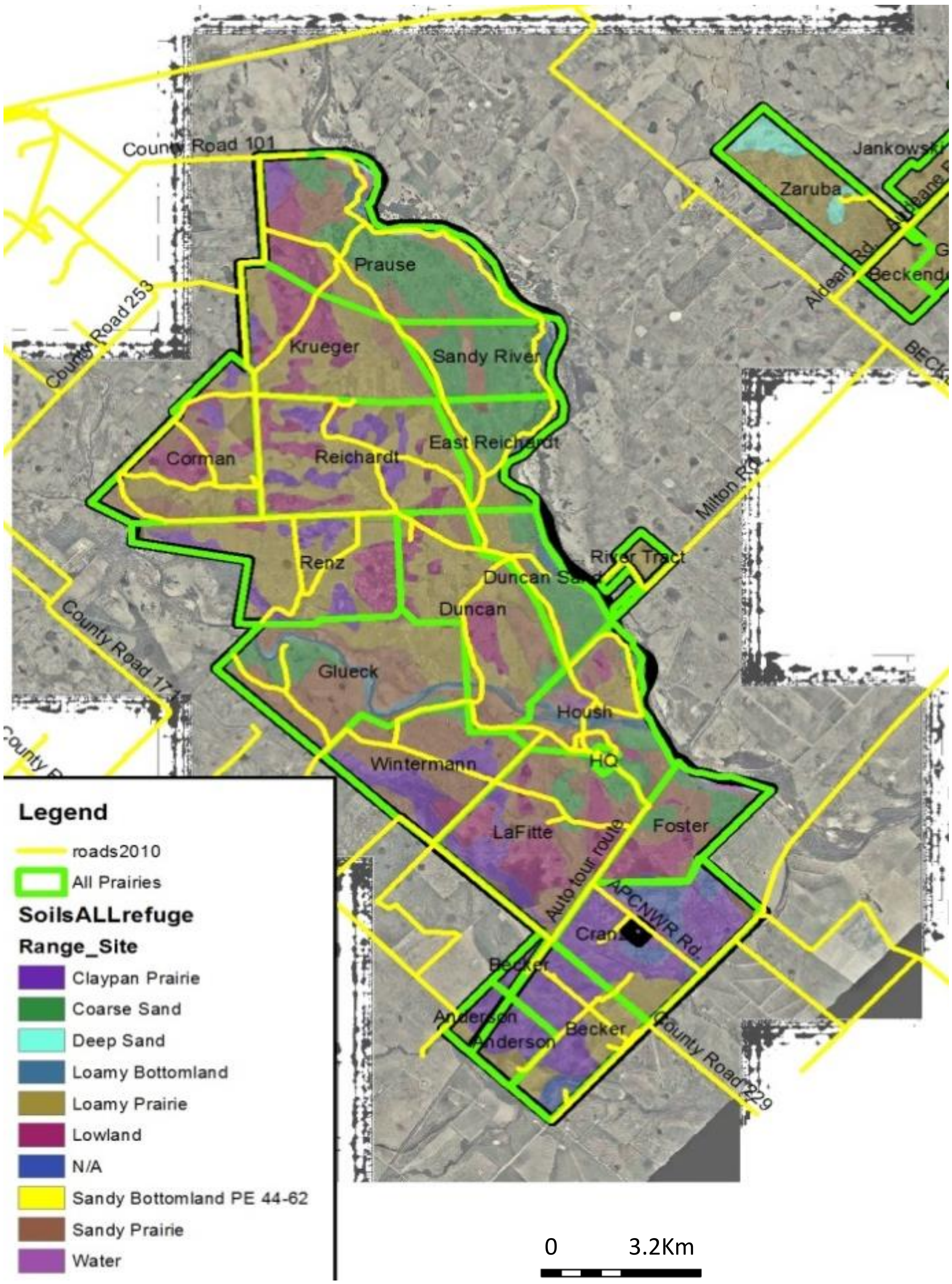


Fig. 1.4. Soil map of Attwater Prairie Chicken National Wildlife Refuge (APCNWR), Colorado and Austin counties, Texas (Rebecca Chester, Biologist, APCNWR, Eagle Lake, Texas, 2010).

sufficient. *Extinguish Plus*^{TM} was applied aerially at 1.7 kg/ha (1.5 lbs/ac) to 1,491 ha (2013) and 2,383 ha (2014) of the 4,265 ha refuge (M. Morrow, APCNWR, personal communication). While the treatment was applied by the U.S. Fish and Wildlife Service to promote Attwater's prairie-chicken recruitment, it allowed an opportunity to determine the effects of large-scale chemical fire ant treatment on northern bobwhite abundance, nest success, and brood survival as well as food invertebrate abundance. The effects of such large-scale treatment of RIFA on northern bobwhites and their food invertebrates have not been studied extensively. The purpose of my research was to determine if large-scale RIFA treatment is an effective method of increasing northern bobwhite abundance.

Research was conducted on treated and non-treated areas of APCNWR. Locations for treatment were selected by U.S. Fish and Wildlife Service personnel to maximize benefit to Attwater's prairie-chicken. This resulted in a number of environmental differences/biases between treated and non-treated areas of the refuge including ecological sites, vegetation composition, rainfall, and predator abundance among others. For example, treated areas consisted largely of claypan prairie and loamy prairie ecological sites, while non-treated areas contained large amounts of coarse sand and corresponding vegetation (Figs. 1.4 and 1.5). Much of the non-treated area was former rice agriculture under restoration to prairie plant communities. Pastures of former agriculture include Cranz, Anderson, Becker, and Renz (Fig. 1.4; M. Morrow, APCNWR, personal communication).

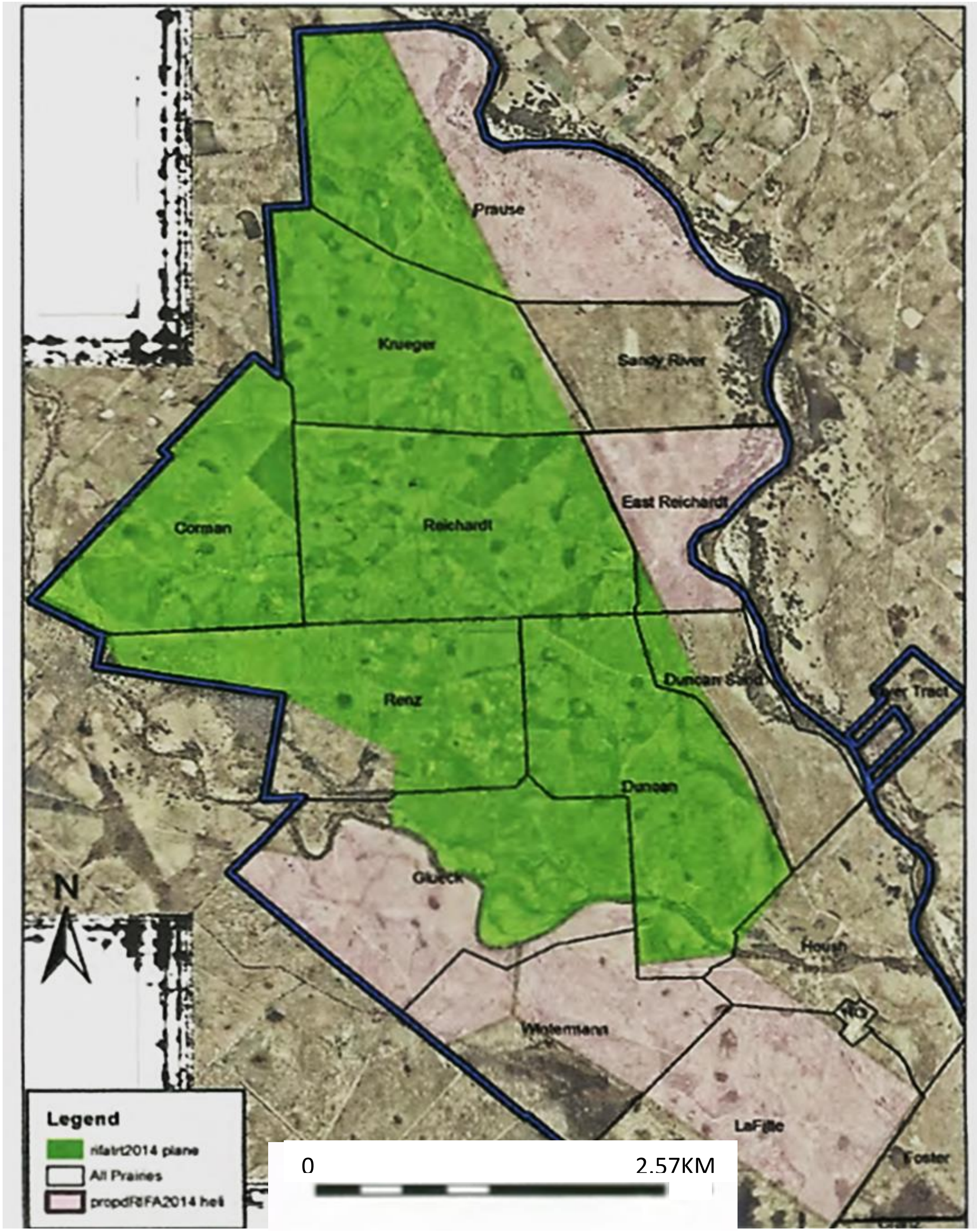


Fig. 1.5. Areas of Attwater Prairie Chicken National Wildlife Refuge (APCNWR), Colorado and Austin counties, Texas treated with *Extinguish Plus*^{TM} in 2013 (green) and 2014 (green and purple) to control for red imported fire ants (Rebecca Chester, Biologist, APCNWR, Eagle Lake, Texas, October 2014).

Differences such as these resulted in a level of bias that may have influenced RIFA, invertebrate, or northern bobwhite abundance in treated and non-treated areas of APCNWR during my study.

CHAPTER II

EFFECTS OF RIFA TREATMENT ON RIFA AND INVERTEBRATE ABUNDANCE

It is known that red imported fire ants (RIFA, *Solenopsis invicta*) will prey on other insects, including important native species (Porter and Savignano 1990). According to Porter and Savignano (1990), arthropod abundance was reduced by 75% following invasion by RIFA. Therefore, RIFA are hypothesized to negatively impact northern bobwhites (*Colinus virginianus*) by preying on insects (Porter and Savignano 1990); a major source of food and water for young bobwhites (Savory 1989, Wojcik et al. 2001, Giuliano et al. 1995, Mueller 1999). RIFA also alter feeding activity of young northern bobwhite chicks which may affect their rate of growth (Pedersen et al. 1996). If a lack of such small insects and other invertebrates exists to feed young northern bobwhite chicks, malnutrition and death may follow hatching.

In October 2013 and again in September–October 2014, portions of the Attwater Prairie Chicken National Wildlife Refuge (APCNWR) were aerially treated with *Extinguish Plus*^{TM}, a chemical pesticide (hydramethylnon) and reproductive inhibitor (S-methoprene) that targets RIFA as a management action to increase Attwater's prairie-chicken (*Tympanuchus cupido attwateri*) brood survival. *Extinguish Plus*^{TM} was applied aerially at 1.7 kg/ha (1.5 lbs/ac) to 1,491 ha (2013) and 2,383 ha (2014) of the 4,265 ha refuge (M. Morrow, APCNWR, personal communication). This large-scale RIFA treatment allowed me to opportunistically study the effects of this treatment on northern bobwhite (*Colinus virginianus*) and the insects used by young bobwhites as food (Savory 1989, Mueller et al. 1999). The first step of this study was to determine the degree to which treatment with *Extinguish Plus*™ the previous fall(s) reduced RIFA abundance on treated areas. The second step involved assessing the presence of invertebrates that were potential food for bobwhite chicks on areas both treated and non-treated during the summer bobwhite nesting seasons. If significantly more invertebrates were found in the treated areas, it could be inferred that RIFA treatment was successful at increasing invertebrate availability for bobwhite chicks.

STUDY AREA

Research was conducted on the 4,265-ha Attwater Prairie Chicken National Wildlife Refuge (APCNWR) which is located approximately 97 km west of Houston, Texas in Colorado and Austin counties. The APCNWR is dedicated to management of the critically endangered Attwater's prairie-chicken (*Tympanuchus cupido attwateri*). According to Lockwood (1998), the refuge is located on the border between the Gulf Prairies and Marshes and the Post Oak Savannah ecoregions. The refuge is bordered primarily by agricultural fields and properties infested with woody vegetation (Lockwood 1998). Common range sites on the refuge include loamy prairie, coarse sand, and claypan prairie (Lockwood 1998). Habitat management practices such as burning, grazing, herbicide treatment, and predator control are used (Lockwood 1998). In Columbus, Texas (16 km west of the refuge) rainfall totaled 105.2 cm in 2014; of which 33.55 cm fell in May (www.ncdc.noaa.gov). The highest rainfall recorded in a 24 hour period during May 2014 was 21.08 cm (www.ncdc.noaa.gov).

Research was conducted on treated and non-treated areas of APCNWR. Locations for treatment were selected by U.S. Fish and Wildlife Service personnel to maximize benefit to Attwater's prairie-chicken. This resulted in a number of environmental differences/biases between treated and non-treated areas of the refuge including ecological sites, vegetation composition, rainfall, and predator abundance among others. For example, treated areas consisted largely of claypan prairie and loamy prairie ecological sites, while non-treated areas contained large amounts of coarse sand and corresponding vegetation (Figs. 1.4 and 1.5, Chapter I). Much of the non-treated area was former rice agriculture under restoration to prairie plant communities. Differences such as these resulted in a level of bias that may have influenced RIFA, invertebrate, or northern bobwhite abundance in treated and non-treated areas of APCNWR during my study.

METHODS

Fire Ant Abundance

RIFA abundance was estimated once monthly during May–August 2014 and April–May 2015 northern bobwhite nesting seasons at 26 locations randomized each month across the treated and non-treated areas of the refuge. This was done by placing 2 baited Petri dishes (3 in June 2014) within 3 m at each site and leaving them exposed to surrounding ants for 20 minutes. Various baits including slices of hot dog, *Meow Mix*

Tender Centers® dry pelleted cat food (Big Heart Pet Brands, San Francisco, California), corn meal, vegetable oil, corn meal soaked in vegetable oil, and sugar cubes were tested for attractiveness/palatability to RIFA. Either 2 or 3 baits were tested each month. Slices of hot dogs were used at every sample site each month as a control for testing different baits. Hot dogs are commonly used for RIFA sampling (Morrow et al. 2015). After 20 minutes of exposure, the dishes were sealed with tape to capture any ants inside and then frozen. Ants were later keyed to species (Cook et al. 2014) and individuals of each species were counted. The total numbers of RIFA collected for both the treated and non-treated areas of the refuge were compared to determine an estimated percent reduction of RIFA following treatment. Chi-square tests were used to determine if there were differences in the number of ant samples with RIFA between treated and non-treated areas (Ott and Longnecker 2008). I also used a Chi-square goodness of fit test to determine if there was a difference in the proportion of hot dog and cat food samples which contained RIFA. This included both treated and non-treated sites.

Invertebrate Abundance

Invertebrate abundance was estimated once monthly during the 2014 and 2015 bobwhite nesting seasons by conducting 2 net sweeps at each of the 26 sites randomly selected each month for estimating RIFA abundance. Data from each of the 2 sweeps at each site were then pooled to obtain a mean estimate of number and biomass of invertebrates for each site. This allowed for the assessment of bobwhite food abundance (represented by invertebrate abundance) in the treated and non-treated areas. Sweep nets

(35 cm aperture; Forestry Suppliers, Jackson, Mississippi) were used to cover an area of approximately 20 m^2 (Randel et al. 2006) per each of the 26 sweep locations each month. This was accomplished by 2 investigators each walking 25 paces in a random direction, sweeping their nets once per pace and alternating the direction of sweep with each pace. Invertebrates collected from each sweep were sealed in 1.8-L storage bags, labeled, and frozen for later sorting to insect Order. For each sample, insects were individually counted, dried in an oven at 66^0 C for 24 hours, and weighed as a unit to the nearest 0.001 g. These methods allowed estimates of invertebrate abundance and composition on both the treated and non-treated areas of the refuge. A 2-sample *t*-test (Ott and Longnecker 2008) was used to compare invertebrate abundance and biomass between the treated and non-treated areas of the refuge by month.

While collecting sweep net samples, I noted if the area had been burned within the last 6 months and/or was being grazed at the time of the sampling. After sorting to Order, drying, and weighing of all 2014 and 2015 insect samples, *t*-tests were run to determine if significant differences in insect abundance existed between treated/non-treated, burned/non-burned, and grazed/non-grazed areas of the refuge. Tests were run separately for biomass and numbers of invertebrates.

RESULTS

Fire Ant Abundance

Across the project's first season (May–August 2014), 1,315 RIFA were found in 17 of 125 samples from areas treated with *Extinguish Plus*^{TM} and 5,959 RIFA were found in 37 of 115 samples from areas not treated. Non-treated areas had 72% more samples with RIFA than did treated areas. During the project's second season (April and May 2015), 108 RIFA were found in 9 of 58 samples in treated areas and 826 RIFA were found in 16 of 46 samples in non-treated areas. Non-treated areas had 69% more samples with RIFA than did treated areas. Overall, 1,423 RIFA were collected in 26 of 183 samples from treated areas and 6,785 RIFA were collected in 53 of 161 samples from non-treated areas. Non-treated areas had 70% more samples with RIFA than did treated areas (Table 2.1). Significantly lower numbers of samples with RIFA were found in treated areas in 2014 ($\chi^2 = 11.850$, $df = 1$, $P < 0.001$) and 2015 ($\chi^2 = 5.214$, $df = 1$, $P < 0.022$).

With a few exceptions, samples within the non-treated areas contained more RIFA than treated areas during both collection seasons. These data suggest that treatment with *Extinguish Plus*^{TM} was successful in reducing RIFA on treated areas during the 2014 and 2015 northern bobwhite nesting seasons.

Other ant species collected at bait sites included crazy ants (*Nylanderia terricola*), leaf cutter ants (*Atta* or *Acromyrmex spp*.), pyramid ants (*Dorymyrmex pyramicus*), and harvester ants (*Pogonomyrmex spp.*). Data (Table 2.1) suggest that ant species other than RIFA had higher abundance in the treated areas in all months except

May 2014 and May 2015. Non-fire ant species numbers peaked in August 2014 with 2,144 ants collected.

When the number of RIFA and non-RIFA ants were combined (Table 2.1), July 2014 was the month with most ants collected followed by August 2014. Again, non-treated areas had more samples with ants than treated areas in 2014 ($\chi^2 = 4.93$, $df = 1$, $P = 0.026$).

Of the various baits tested for attractiveness/palatability to ants throughout my study, hot dogs and cat food attracted more RIFA than vegetable oil, cornmeal, cornmeal soaked in vegetable oil, and sugar cubes (Table 2.2). In July 2014 and April 2015, dry pelleted cat food had more RIFA than did hot dogs. However, in May 2015, more RIFA

Table 2.1. Total ants and total RIFA (sample size in parentheses) collected in each month's sampling by treatment/non-treatment on Attwater Prairie Chicken National Wildlife Refuge), Colorado and Austin counties, Texas, 2014–2015.

Month/year	**Treated total**	**Non-treated total**	**Treated RIFA**	**Non-treated RIFA**
May 2014	130(26)	1,924(26)	1(26)	1,054(26)
June 2014	320(42)	2,441(36)	134(42)	2,318(36)
July 2014	1,257(33)	2,613(25)	906(33)	2,379(25)
August 2014	2418(24)	1,085(28)	274(24)	208(28)
April 2015	292(26)	998(26)	5(26)	768(26)
May 2015	211(32)	410(20)	103(32)	58(20)
Total	4,628(183)	9,471(161)	1,423(183)	6,785(161)

were found in hot dog samples. Overall, there was no statistical difference (χ^2 = 2.302, *df* = 1, *P* = 0.129) between hot dogs and cat food in the number of samples with RIFA; however, 30 of 72 cat food samples had RIFA, whereas only 18 of 72 hot dog samples had RIFA.

Table 2.2. Numbers of RIFA collected per bait variety by month on Attwater Prairie Chicken National Wildlife Refuge (APCNWR), Colorado and Austin counties, Texas, 2014–2015. For each bait variety, 26 samples were taken each month.

Month /year	**Hot dog**	**Oil**	**Cornmeal**	**Oil/Cornmeal**	**Cat food**	**Sugar**	**Total**
May 2014	869	186	N/A	N/A	N/A	N/A	1,055
June 2014	1,641	N/A	182	629	N/A	N/A	2,452
July 2014	578	N/A	N/A	N/A	2707	N/A	3,285
August 2014	478	N/A	N/A	N/A	N/A	4	482
April 2015	238	N/A	N/A	N/A	535	N/A	773
May 2015	97	N/A	N/A	N/A	64	N/A	161

Invertebrate Abundance

During the month of June 2014 (*P* = 0.012), 2014 overall (*P* = 0.029), and both years combined overall (*P* = 0.019), samples from treated areas yielded a significantly lower mean biomass (Table 2.3) of insects per sample than non-treated areas. This suggests that a higher biomass of insects exists in non-treated areas in 2014. However, my results suggest that a significantly higher number (Table 2.3) of insects existed in treated areas during the month of April 2015 (*P* = 0.003).

When comparing burned and non-burned pastures with invertebrate biomass (Table 2.4) by month, the May 2014 sample yielded a significant (*P* = 0.023) difference with a higher mean biomass of invertebrates collected in non-burned areas during this month. However, results also found a significantly ($P = 0.049$) higher numbers (Table 2.4) of insects in burned areas during August 2014.

When comparing grazed and non-grazed pastures for differences in invertebrate biomass (Table 2.5) by month, no significance differences were found. However, data for 2014 overall ($P = 0.032$) had higher insect numbers in non-grazed areas.

The numbers of individuals of each invertebrate Order/group collected varied by month (Fig. 2.1). Orthopterans were the most collected invertebrates in July 2014, April 2015, and May 2015; tying with Coleopterans in May 2014. Spiders were the most collected invertebrates in June 2014 and August 2014. Either Orthopterans or spiders were the most collected invertebrates each month except for May 2014. Therefore, my data suggest that Orthopterans and spiders were the most prevalent invertebrate groups on the APCNWR in 2014 and 2015.

Table 2.3. Mean and standard deviation (SD) biomass (grams) and numbers of invertebrates by month in treated and non-treated areas on Attwater Prairie Chicken National Wildlife Refuge, Colorado and Austin counties, Texas, 2014–2015

	Treated			**Non-treated**			
Month	x̄	SD	N	x̄	SD	N	***P*-value**
May 2014							
Biomass	0.241	0.131	11	0.300	0.124	14	0.261
Numbers	31.5	20.7	11	27.8	27.8	14	0.626
June 2014							
Biomass	0.165	0.095	14	0.351	0.206	12	0.012[a]
Numbers	16.5	8.15	14	18.5	14.1	12	0.658
July 2014							
Biomass	0.393	0.330	15	0.622	0.427	11	0.155
numbers	24.9	15.1	15	25.9	11.2	11	0.853
August 2014							
Biomass	0.329	0.231	12	0.448	0.546	14	0.471
Numbers	21.8	7.72	12	22.7	22.1	14	0.882
April 2015							
Biomass	0.167	0.152	13	0.158	0.126	13	0.876
Numbers	57.4	26.8	13	28	13.8	13	0.003
May 2015							
Biomass	0.153	0.086	16	0.217	0.107	10	0.128
Numbers	25.4	16.1	16	31.1	12.8	10	0.330
2014 Overall							
Biomass	0.285	0.235	52	0.422	0.377	51	0.029[a]
Numbers	23.3	14.3	52	23.8	16.4	51	0.865
2015 Overall							
Biomass	0.159	0.118	29	0.184	0.119	23	0.46
Numbers	39.7	26.6	29	29.3	13.1	23	0.073
Overall							
Biomass	0.240	0.209	81	0.348	0.337	74	0.019[a]
Numbers	29.2	21	81	25.5	15.6	74	0.219

[a]Indicates a significant trend in an opposite direction as predicted.

Table 2.4. Mean and standard deviation (SD) biomass (grams) and numbers of invertebrates by month in burned and non-burned areas on Attwater Prairie Chicken National Wildlife Refuge, Colorado and Austin counties, Texas, 2014–2015.

	Burned			Non-burned			
Month	$\bar{x}$	**SD**	**N**	$\bar{x}$	**SD**	**N**	***P*-value**
May 2014							
Biomass	0.213	0.089	11	0.323	0.136	14	0.023
Numbers	27.3	17.2	11	31.1	18	14	0.589
June 2014							
Biomass	0.260	0.150	12	0.243	0.207	14	0.808
Numbers	17.5	5.17	12	17.4	14.6	14	0.973
July 2014							
Biomass	0.644	0.483	8	0.421	0.324	18	0.263
Numbers	29.3	12.5	8	23.6	13.7	18	0.032
August 2014							
Biomass	0.602	0.608	10	0.263	0.187	16	0.118
Numbers	32.7	23.3	10	15.75	6.43	16	0.049
April 2015							
Biomass	0.151	0.199	6	0.166	0.119	20	0.87
Numbers	32.1	16.1	6	45.9	27.5	20	0.146
May 2015							
Biomass	0.111	0.055	2	0.183	0.099	24	0.345
Numbers	22.5	8.49	2	28	15.3	24	0.567
2014 Overall							
Biomass	0.406	0.412	41	0.318	0.237	62	0.221
Numbers	26.1	16.2	41	21.9	14.5	62	0.177
2015 Overall							
Biomass	0.141	0.171	8	0.175	0.108	44	0.598
Numbers	29.7	14.6	8	36.1	23.2	44	0.321
Overall							
Biomass	0.363	0.394	49	0.259	0.206	106	0.088
Numbers	26.7	15.9	49	27.8	19.8	106	0.719

Table 2.5. Mean and standard deviation (SD) biomass (grams) and numbers of invertebrates by month in grazed and non-grazed areas on Attwater Prairie Chicken National Wildlife Refuge Colorado and Austin counties, Texas, 2014–2015.

	Grazed			Non-grazed			
Month	$\bar{x}$	**SD**	**N**	$\bar{x}$	**SD**	**N**	***P*-Value**
May 2014							
Biomass	0.257	0.093	9	0.284	0.146	16	0.569
Numbers	22.3	6.52	9	33.4	20.3	16	0.059
June 2014							
Biomass	0.313	0.238	10	0.212	0.126	16	0.242
Numbers	15.6	4.84	10	18.6	13.7	16	0.438
July 2014							
Biomass	0.499	0.420	17	0.472	0.328	9	0.860
Numbers	21.6	10.5	17	32.3	15.9	9	0.094
August 2014							
Biomass	0.376	0.429	19	0.440	0.453	7	0.751
Numbers	20.9	11.8	19	25.9	27.1	7	0.66
April 2015							
Biomass	0.144	0.090	4	0.166	0.145	22	0.701
Numbers	71.8	29.7	4	37.4	21.7	22	0.115
May 2015							
Biomass	0.142	0.105	8	0.194	0.093	18	0.249
Numbers	26.1	20.6	8	28.2	12.2	18	0.798
2014 Overall							
Biomass	0.383	0.363	55	0.318	0.260	48	0.298
Numbers	20.4	9.82	55	27.2	19.3	48	0.032
2015 Overall							
Biomass	0.142	0.096	12	0.179	0.124	40	0.298
Numbers	41.3	31.9	12	33.3	18.4	40	0.419
Overall							
Biomass	0.34	0.344	67	0.255	0.219	88	0.080
Numbers	24.1	17.7	67	29.9	19	88	0.053

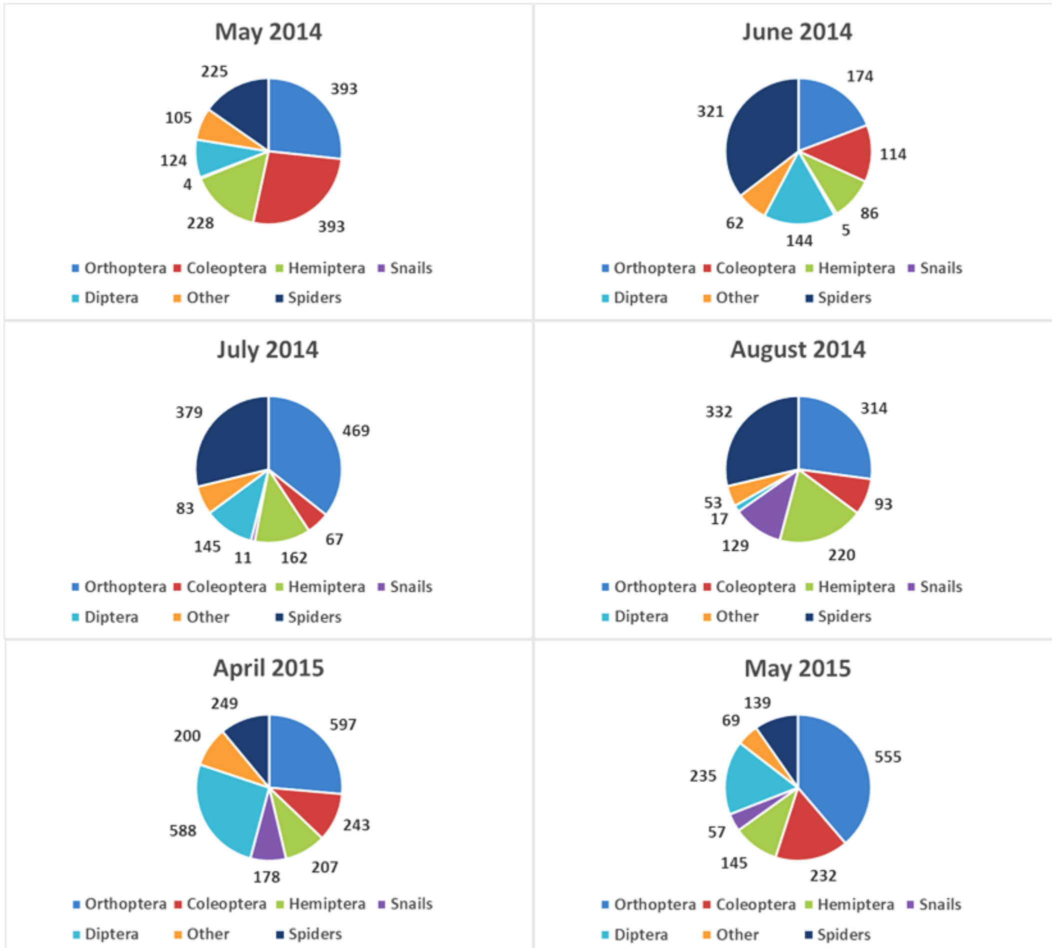
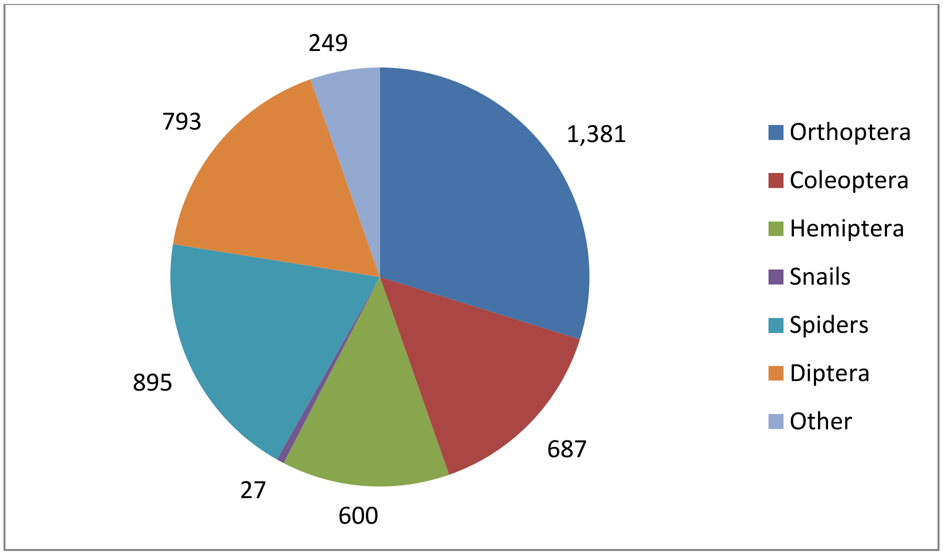


Fig. 2.1. Invertebrates collected by group by month on Attwater Prairie Chicken National Wildlife Refuge, Colorado and Austin counties, Texas, 2014–2015.

The numbers of individual invertebrates from each group collected varied by treatment/non-treatment (Fig. 2.2). Fewer snails were found in treated areas, and more of each other insect group were found in treated areas. It is worth noting that more samples were taken from treated areas (n = 83) than non-treated areas (n = 73) and that this may have influenced my results.



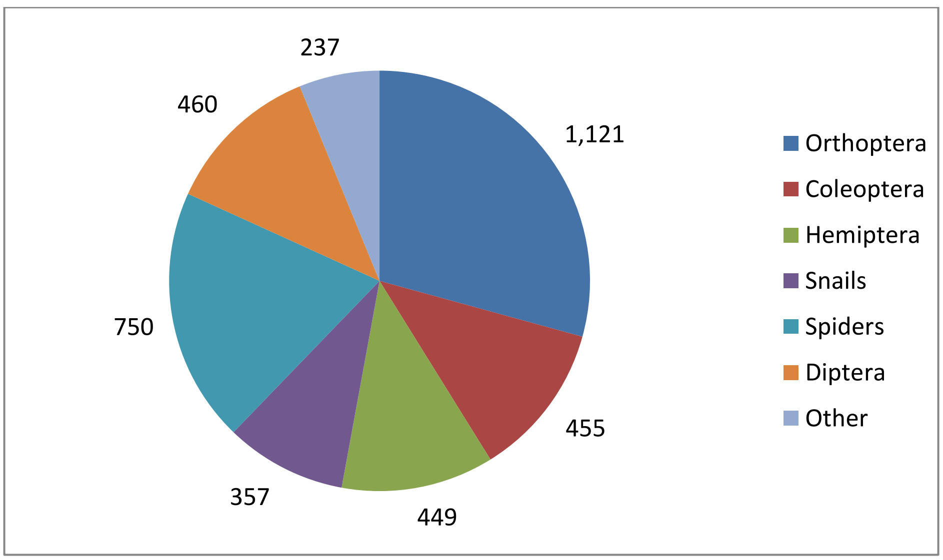


Fig. 2.2. Total invertebrates collected by group in treated (top, *n* = 83) and non-treated (bottom, *n* = 73) areas of Attwater Prairie Chicken National Wildlife Refuge, Colorado and Austin counties, Texas, 2014–2015.

DISCUSSION

Fire Ant Abundance

My results suggest that treatment with *Extinguish Plus*^{TM} succeeded in reducing RIFA on the refuge in 2014 and 2015. This result is consistent with that of a similar study on the APCNWR by Morrow et al. (2015) which concluded that treatment significantly reduced RIFA. My result also is consistent with that of Aubuchon et al. (2006), who found decreased abundance of RIFA on 2 different 8 ha grazed pastures in Alabama that had been treated with *Extinguish Plus*^{TM}; an earlier form of *Extinguish Plus*^{TM} containing methoprene, but not hydramethylnon. Mitchell and Knutson (2004), as well, found RIFA presence in 2 peanut fields reduced by 85–98% after treatment with *Extinguish*. Hara et al. (2011) saw 97% reduction of little fire ants (*Wasmannia auropunctata*) in potted nursery plants after treatment with *Extinguish Plus*^{TM}.

During my project, ant species other than RIFA appeared to have higher abundance in treated areas than non-treated areas in every month of sampling except May 2014 and May 2015. This may suggest that native ants recovered more quickly from treatment than did RIFA. It also may suggest that reduction of RIFA had a positive effect on native ants which outweighed the negative effect of treatment (Calixto et al. 2007, Wilder et al. 2013). As well, RIFA may have become more nocturnal than native ants as the summer temperatures rose, which left my samples collected during daylight hours with fewer RIFA than expected (Vogt et al. 2003). However, a study by Mokkarala (2002) found that 2 non-target ant species, the thief ant (*Solenopsis molesta*) and the little black ant (*Monomorium minimum*), were negatively influenced to the same degree as RIFA by treatment with a metabolic inhibitor (*Amdro*^{TM}) and an insect growth regulator (*Logic*^{TM}). My RIFA collection results coupled with those of Morrow et al. (2015), suggest that use of *Extinguish Plus*^{TM} is an effective method of RIFA reduction that would be useful to wildlife managers on the coastal prairie.

In my study, dry pelleted cat food and hot dogs proved to be the most attractive/palatable baits to RIFA of the baits that I tested. The other baits tested did not appear to have near the attractiveness to RIFA of cat food and hot dogs, as far fewer numbers were collected in those other baits. It is possible the odor and high fat content of the cat food and hot dogs resulted in their success as bait for RIFA.

Dry pelleted cat food attracted as many RIFA as did hot dogs. Cat food is relatively non-greasy, does not require refrigeration, and does not stick to ants in a Petri dish; which makes its use in field work clean and efficient. For these reasons, I would recommend dry pelleted cat food over hot dogs or other food baits for attracting/capturing RIFA.

Invertebrate Abundance

Invertebrate biomass data collected in 2014 suggests lower biomass of insects in treated areas than non-treated and no significant differences between burned/non-burned or grazed/non-grazed areas. Data for 2014 suggest no significant differences in the number of invertebrates in treated/non-treated or burned/non-burned areas, but more insects in non-grazed areas than grazed areas.

Invertebrate biomass data collected in 2015 suggests no differences in insect abundance between treated/non-treated, burned/non-burned, and grazed/non-grazed areas. Data for 2015 overall suggest no significant differences in the number of invertebrates in treated/non-treated, burned/non-burned or grazed/non-grazed areas.

My overall (2014 and 2015) invertebrate biomass data suggests lower biomass of insects in treated areas than non-treated and no significant differences between burned/non-burned or grazed/non-grazed areas. In contrast, data for the number of invertebrates suggests no significant differences between treated/non-treated, burned/non-burned, or grazed/non-grazed areas. These results suggest no evidence that treatment with *Extinguish Plus*^{TM} significantly improved invertebrate abundance during these 2 study years. However, sampling suggests that insects were smaller in size within treated areas (due to lower mean biomass in treated areas and no significance in difference of mean numbers), which may suggest the presence of more available food to young northern bobwhite chicks. Considering the higher numbers of snails present in non-treated areas and that snails are generally heavier than other insects, it also is possible this abundance of snails in non-treated areas led to a higher mean biomass of samples. Snails were abundant; particularly in the month of August 2014. This could have been due to snails leaving the ground and climbing vegetation as summer temperatures rose and the soil dried, which allowed more snails to be captured in nets. It is also noteworthy that all of the remaining invertebrate categories had more individuals for treatment than non-treatment. As well, it is worth noting that more samples were collected in treated areas (n = 83) than non-treated areas (n = 73), and that this may have influenced my results.

The APCNWR received higher-than-average rainfall in the spring months of both 2014 and 2015 (www.ncdc.noaa.gov). It is possible that heavy rains and the resulting abundant vegetation in both 2014 and 2015 facilitated the production of more insects than RIFA could significantly influence through predation. The replication of this study over a normal and/or dry season with less vegetative growth may yield different results.

A similar study of insect abundance was conducted on the APCNWR in 2011 and 2012 by Morrow et al. (2015). Their study concluded that no difference in invertebrate abundance existed between treated and non-treated areas on this particular refuge; however, Morrow et al. (2015) did observe higher invertebrate abundance in treated areas of several other sites studied. Morrow et al. (2015) results for the APCNWR are consistent with the results of my study. Other studies have documented reduction of invertebrates through vegetative disturbance by burning and grazing (Kim and Holt 2012, Branson and Haferkamp 2014), which is not consistent with my results. However, others have documented increases in invertebrates after patch-burning (Fuhlendorf and Engle 2001, Roper 2003).

It was noted that much of the non-treated areas consisted of coarse sand ecological site and that much of the treated areas consisted of claypan prairie and loamy prairie (Fig 1.4, Chapter I). These ecological sites each support different soils and vegetation. In addition, the non-treated area consisted of a much higher proportion of former agriculture than the treated area. It is possible that these or other environmental differences influenced my results.

CHAPTER III

IMPACTS OF RIFA TREATMENT AND INVERTEBRATE ABUNDANCE ON NORTHERN BOBWHITE BROOD SURVIVAL

It is known that red imported fire ants (RIFA, *Solenopsis invicta*) will prey on newly-hatched northern bobwhite chicks (*Colinus virginianus*; Mueller et al. 1999). According to Giuliano (1996), bobwhite chicks experienced reduced survival when exposed to RIFA for even a short time. Wildlife scientists (Allen et al. 1995, Giuliano et al. 1996, Mueller et al. 1999) have long speculated the invasion of RIFA onto northern bobwhite habitat may be contributing to the decline of quail across the southern United States.

The importance of invertebrates as food for young chicks of gallinaceous bird species, including the northern bobwhite, is well documented (Savory 1989, Wojcik et al. 2001). Giuliano et al. (1995) determined that food insects provide an essential source of water intake for bobwhites. Mueller (1999) observed that RIFA had a negative influence on northern bobwhite brood survival and hypothesized that by preying on insects and other small invertebrates, RIFA may reduce food on which northern bobwhite chicks depend.

In October 2013 and again in September–October 2014, the Attwater Prairie Chicken National Wildlife Refuge (APCNWR) was treated aerially with *Extinguish Plus*^{TM} a chemical pesticide and reproductive inhibitor that targets RIFA in an attempt to increase Attwater's prairie-chicken (*Tympanuchus cupido attwateri*) brood survival.

Extinguish Plus™ was applied aerially at 1.7 kg/ha (1.5 lbs/ac) to 1,491 ha (2013) and 2,383 ha (2014) of the 4,265 ha refuge (M. Morrow, APCNWR, personal communication). This large-scale treatment provided an opportunity to study its effects on northern bobwhite nest success and brood survival. If significantly more northern bobwhite chicks survived to fledgling age and more fledglings survived to adulthood in the treated areas of the refuge than in the non-treated areas, it could be inferred that chemical reduction of RIFA was successful at increasing northern bobwhite nest success and brood survival.

STUDY AREA

Research was conducted on the 4,265-ha Attwater Prairie Chicken National Wildlife Refuge (APCNWR) which is located approximately 97 km west of Houston, Texas in Colorado and Austin counties. The APCNWR is dedicated to management of the critically endangered Attwater's prairie-chicken (*Tympanuchus cupido attwateri*). According to Lockwood (1998), the refuge is located on the border between the Gulf Prairies and Marshes and the Post Oak Savannah ecoregions. The refuge is bordered primarily by agricultural fields and properties infested with woody vegetation (Lockwood 1998). Common range sites on the refuge include loamy prairie, coarse sand, and claypan prairie (Lockwood 1998). Habitat management practices such as burning, grazing, herbicide treatment, and predator control are used (Lockwood 1998). In Columbus, Texas (16 km west of the refuge) rainfall totaled 105.2 cm in 2014; of which 33.55 cm fell in May (www.ncdc.noaa.gov). The highest rainfall recorded in a 24 hour period during May 2014 was 21.08 cm (www.ncdc.noaa.gov).

Research was conducted on treated and non-treated areas of APCNWR. Locations for treatment were selected by U.S. Fish and Wildlife Service personnel to maximize benefit to Attwater's prairie-chicken. This resulted in a number of environmental differences/biases between treated and non-treated areas of the refuge including ecological sites, vegetation composition, rainfall, and predator abundance among others. For example, treated areas consisted largely of claypan prairie and loamy prairie ecological sites, while non-treated areas contained large amounts of coarse sand and corresponding vegetation (Figs. 1.4 and 1.5, Chapter I). Much of the non-treated area was former rice agriculture under restoration to prairie plant communities. Differences such as these resulted in a level of bias that may have influenced RIFA, invertebrate, or northern bobwhite abundance in treated and non-treated areas of APCNWR during my study.

METHODS

Beginning in April 2014, the start of the northern bobwhite nesting season and 6 months following treatment with *Extinguish Plus*^{TM}, northern bobwhites were trapped in areas both treated and not treated with *Extinguish Plus*^{TM} using funnel traps (Kuvlesky 1989). Trap locations were selected based on the following criteria: locations near heavy escape cover, locations visible to the investigators from a vehicle on refuge roads, locations relatively hidden from public view, and locations near epicenters of audible northern bobwhite mating calls or northern bobwhite sightings. Potential trap locations were pre-baited weekly with commercially-purchased grain mixes which included cracked corn, milo, sunflower, millet, and wheat seeds. Pre-baiting continued until trap locations were selected based on grain disappearance week-to-week.

Once promising locations were chosen and following at least a week of pre-baiting, trapping began. Twice-weekly trips to the refuge consisted of baiting all chosen sites, placing a funnel trap at each site, and checking all sites hourly for trapped northern bobwhites. All non-target animals trapped were immediately released and a note was made regarding the species and quantity trapped. All northern bobwhites trapped were aged by primary covert color, sexed by head color (Lyons et al. 2012), weighed, banded with a size 7 blue colored band (National Band and Tag Company, Newport, Kentucky) on the right leg, and (up to 40) fitted with an 8.8g (approximately 4% body weight) radio transmitter (Fig. 3.1.; 150MHz; Wildlife Materials, Carbondale, Illinois). Approximately half of the available radio transmitters were fitted on females in the treated area, and approximately half were fitted on females in the non-treated area.

Initially, I was going to determine nest success, however, during 2014, no attempts were made to locate active nests as Mueller et al. (1999) observed high abandonment rates while attempting to locate active nests and therefore no data were collected on nest success in 2014. As well, only 5 hens had been fitted with radio transmitters by 1 June 2014, providing a very small sample size of potentially nesting hens. However, due to a project end-date of 31 May 2015 and 47 hens radioed by June 1 2015, attempts were made in 2015 to locate all female northern bobwhites with radios (by radio triangulation) twice weekly which were located in a specific area during a given week to check for nesting status. Hens suspected of nesting were located using a hand-held 3-element yagi antenna (Wildlife Materials, Carbondale, Illinois). Confirmed nests were noted and checked regularly for signs of predation. Because the study ended

Figure 3.1. Female northern bobwhite fitted with a leg band and radio transmitter on Attwater Prairie Chicken National Wildlife Refuge, Colorado County, Texas.

on 31 May 2015, I had no data on nest success for 2015.

Mark-recapture methods (Pierce et al. 2012) were used to calculate estimates of adult bobwhite abundance near our traps prior to reproduction in 2014 and 2015. I used a modified Schnabel method using only known (recaptured or observed after each estimate) adult birds alive at the time of each estimate as the total number marked (Silvy et al. 1977) to obtain conservative abundance estimates of northern bobwhite using my trap sites.

To estimate brood survival in treated and non-treated areas without influencing brood survival by flushing radio-tagged hens with broods during 2014, I recorded all females sighted or trapped with and without broods in treated and non-treated areas and recorded the number of chicks per brood. These data were collected once the first brood was sighted on 10 June 2014. Broods were sighted while driving refuge roads while collecting data for other aspects of this study. I used a Chi-square goodness of fit test to determine differences in number of hens with and without broods located in treated and non-treated areas. I used a 2-sample *t*-test to determine differences in the mean number of chicks per broods for hens located in the treated and non-treated areas.

Throughout this study of northern bobwhites and RIFA on the Attwater Prairie Chicken National Wildlife Refuge, many individuals of non-target animal species were unintentionally captured in funnel traps baited with grain mixes. These animals were immediately released and documented. This unintended capture data can be used as a guide to determine what animals may be captured using similar methods to those used in this study of northern bobwhites. This information could be useful to anyone studying small granivores within the Gulf Prairie region of Texas.

RESULTS

Trapping and Marking

In 2014, 11 traps were established in the non-treated area and 16 traps in the treated area and in 2015, 12 traps were established in the non-treated area and 20 traps were established in the treated areas. From March 2014 through May 2015, 284 northern bobwhites (142 males, 91 females, and 51 chicks too young to be sexed) were trapped and banded (Table 3.1). Over the course of the project, 239 recaptures took place. During this time, 111 bobwhites were recaptured up to 3 times, and 65 were recaptured 4 times or more. One bobwhite male was recaptured 8 times.

Schnabel methods (Pierce et al. 2012) were used to calculate estimated adult northern bobwhite abundance in the vicinity of our traps prior to reproduction each year. May 2014 had an estimated abundance of 41 bobwhites (27 in treated area and 14 in non-treated area). June 2014 had an estimated abundance of 83 individuals (54 treated and 29 non-treated). May 2015 had an estimated abundance of 82 bobwhites (49 treated and 33 non-treated). These data suggest higher bobwhite abundance in treated trap sites than in non-treated trap sites. However, it is worth noting that more trap sites were

Table 3.1. Number of northern bobwhite trapped by sex, age, and year in treated and non-treated areas on Attwater National Wildlife Refuge, Colorado and Austin counties, Texas, March–December 2014 and March–May 2015. Treated areas had 16 traps in 2014 and 20 traps in 2015. Non-treated areas had 11 traps in 2014 and 12 traps in 2015 (Mean catches per trap site in parentheses).

	Adults/juveniles		Hatch year			
Treatment/year	Male	Female	Male	Female	Unknown	Total
Treated 2014	42(2.6)	22(1.4)	2(0.1)	1(0.06)	23(1.4)	90(5.6)
Non-treated 2014	28(2.5)	16(1.5)	3(0.3)	7(0.6)	28(2.5)	82(7.5)
Total 2014	70(2.6)	38(1.4)	5(0.2)	8(0.3)	51(1.9)	172(6.4)
Treated 2015	34(1.7)	24(1.2)	0	0	0	58(2.9)
Non-treated 2015	33(2.8)	21(1.8)	0	0	0	54(4.5)
Total 2015	67(2.1)	45(1.4)	0	0	0	111(3.5)
Total	137(2.3)	83(1.4)	5(0.8)	8(0.1)	51(0.9)	284(4.8)

located in treated areas (16 in 2014 and 20 in 2015) than non-treated areas (11 in 2014 and 12 in 2015).

Several bobwhites were recaptured far from the site at which they were initially trapped. The farthest minimum distance traveled by a male between traps was 2,526 m in 48 days. The farthest minimum distance traveled by a female between traps was 2,482 m in 43 days. No birds captured in the treated areas were recaptured in or were observed to move into a non-treated area. The same held for birds captured in non-treated areas. However, 2 individual bobwhites were known to have moved over 2,000 m during my project.

Nests Located

Only 1 nest was found (incidentally) during the 2014 nesting season, and all eggs were found destroyed shortly after the nest's discovery. During May 2015, 2 nests were located (1 with 16 eggs and the second with 15 eggs). At the end of this study, both nests were still being incubated. The nest found in 2014 and one of the nests found in 2015 were located in a treated area while the second nest found in 2015 was located in a non-treated area.

Brood Survival

In 2014, no significant ($\chi^2 = 1.750$, $df = 1$, $P = 0.186$) difference was found in the number of hens sighted with broods vs. without between the treated ($n = 123$ hens, $n = 26$ hens with broods) and non-treated areas ($n = 120$ hens, $n = 37$ hens with broods). The treated areas yielded a mean of 4.42 chicks per brood sighted compared to 7.41 chicks per brood in non-treated areas. Non-treated areas held a significantly ($P = 0.001$) larger mean brood size, which is a trend opposite that which I hypothesized. The data suggest that more quail chicks survived in non-treated areas (Table 3.2). Further support of this was the fact that more ($n = 28$) hatch-year chicks were trapped in 11 traps in the non-treated sites than the hatch-year chicks ($n = 23$) trapped in the 16 treated site traps.

Table 3.2. Number with mean (and standard deviation) size of broods sighted by treatment/non-treatment on Attwater Prairie Chicken National Wildlife Refuge (APCNWR), Colorado County, Texas, 2014–2015.

Month	**Broods treated**	**Broods non-treated**	**Mean chicks treated**	**Mean chicks non-treated**	***P*-value**
June 2014	2	7	3.50 (3.54)	8.57 (3.78)	0.329
July 2014	18	14	4.78 (2.76)	7.86 (4.11)	0.025
August 2014	6	16	3.67 (2.34)	6.50 (4.66)	0.077
Overall	26	37	4.42 (2.66)	7.41 (4.27)	0.001

Unintended Captures

Eighteen species other than northern bobwhites were captured over the course of this study (Table 3.3). With 539 captures, mourning doves (*Zenaida macroura*) were more frequently trapped than all other non-target species. Other often-captured species included red-winged blackbirds (*Agelaius phoeniceus*), white-crowned sparrows (*Zonotrichia leucophrys*), hispid cotton rats (*Sigmodon hispidus*), northern cardinals (*Cardinalis cardinalis*), brown-headed cowbirds (*Molothrus ater*), cottontail rabbits (*Sylvilagus floridanus*), and Brewer's blackbirds (*Euphagus cyanocephalus*). A few species of interest with only a few captures included 1 dickcissel (*Spiza Americana*), 1 Eurasian collared dove (*Streptopeli adecaocto*), 1 common ground dove (*Columbina passerine*), 1 upland sandpiper (*Bartramia longicauda*), 2 meadowlarks (*Sturnella spp.*), 3 13-lined ground squirrels (*Spermophilus tridecemlineatus*), and 4 northern mockingbirds (*Mimus polyglottos*).

Table 3.3. Number of unintended captures by species, month, and year on Attwater Prairie Chicken National Wildlife Refuge (APCNWR), Colorado and Austin counties, Texas, 2014–2015.

Species	**Apr 14**	**May 14**	**Jun 14**	**Jul 14**	**Aug 14**	**Sep 14**	**Oct 14**	**Nov 14**	**Dec 14**	**Mar 15**	**Apr 15**	**May 15**	**Tot**
Brewer's blackbird	24	1	0	0	0	0	1	0	0	0	0	0	26
Brown-headed cowbird	0	0	1	0	0	0	0	0	0	3	15	30	49
Common grackle *Quiscalus quiscula*	0	0	0	0	0	0	0	0	0	0	34	2	36
Eurasian collared dove	0	0	1	0	0	0	0	0	0	0	0	0	1
Hispid cotton rat	0	1	3	11	1	0	1	0	0	0	27	67	110
Cottontail rabbit	3	0	7	9	0	0	0	0	0	1	10	21	51
Common Ground dove	0	1	0	0	0	0	0	0	0	0	0	0	1
Meadow lark	1	0	0	0	0	0	0	0	0	1	0	0	2
Mourning dove	47	36	92	48	4	4	10	12	1	10	163	112	539
Northern cardinal	0	2	4	2	1	0	0	0	0	0	25	43	77
Northern mocking bird	0	0	0	4	0	0	0	0	0	0	0	0	4

Table 3.3. (Cont.)

Species	Apr 14	May 14	Jun 14	Jul 14	Aug 14	Sep 14	Oct 14	Nov 14	Dec 14	Mar 15	Apr 15	May 14	Tot
Norway rat *Rattus norvegicus*	2	0	1	0	0	1	0	0	0	0	0	0	4
Red-winged blackbird	1	1	1	0	0	0	0	0	0	31	85	36	155
Upland sandpiper	0	0	0	0	0	0	0	0	0	0	1	0	1
Vesper sparrow *Pooecetes gramineus*	0	0	0	0	0	0	0	0	0	0	6	0	6
White-crowned sparrow	0	0	0	0	0	0	0	0	0	10	71	3	84
13-lined ground squirrel	1	0	0	0	0	0	0	0	0	0	2	1	4
House sparrow *Passer domesticus*	0	0	0	0	0	0	0	0	0	0	0	1	1
Dickcissel	0	0	0	0	0	0	0	0	0	0	0	1	1

Unintended capture data for each species was divided by the total hours (416.25) of trapping time over the course of the project to calculate a number of captures per hour by species (Fig. 3.2). This provides a rate of capture for each species, which may be more useful than raw numbers captured as trapping hours were not consistent between months. Mourning doves were the most often captured species (1.29/hour) by a large margin. Red-winged blackbirds were the second most often captured species (0.372/hour) other than northern bobwhite.

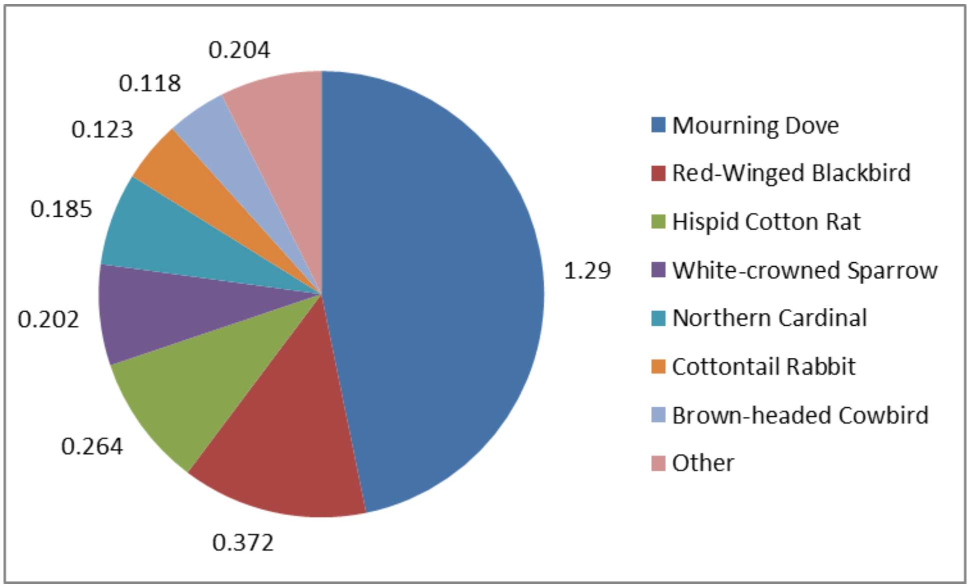


Fig. 3.2. Unintended captures per hour of trapping by species on Attwater Prairie Chicken National Wildlife Refuge, Colorado County, Texas, 2014–2015.

DISCUSSION

Trapping and Marking

My Schnabel estimates of adult bobwhite abundance provided an approximate number of individuals within the vicinity of my bait sites. Trapping began in May 2014; thus, it is likely the lower estimated abundance during this month is partly due to having fewer bobwhites marked than in following months (Silvy et al. 1977). Adult bobwhite estimates were higher in treated sites (65% of total in June 2014 and 60% in May 2015) than non-treated sites. However, more traps were placed in treated areas (59.3% of total in 2014 and 62.5% in 2015); therefore, estimates of adult bobwhite abundance by treatment mirrored the number of traps in treated and non-treated areas. As well, this was probably a reflection of area encompassed by the traps and subsequent bobwhite abundance estimates.

The mean number of bobwhites captured per trap site was higher in non-treated (2014 = 7.5 and 2015 = 4.5) than treated (2014 = 5.6 and 2015 = 2.9) areas during both years (Table 3.1). These data suggest that bobwhite densities were greater in non-treated areas. Because the area covered by traps in the non-treated area was smaller than the area covered by traps in the treated area, the bobwhite population estimates per area reflect more of the area size difference than bobwhite density estimates.

Allen et al. (1995) found, where northern bobwhite densities (call counts) were monitored for 2 years after treatment on 5 treated and 5 non-treated areas, that only in the 2nd year after treatment were autumn bobwhite densities higher (P = 0.028) on treated areas. Other animals trapped during this study probably reduced the number of northern bobwhites trapped, as bobwhites tended to avoid traps which had other animals within.

Nest Success and Brood Survival

My data on northern bobwhite nest success was limited to the point that I could not determine if treatment influenced nest success. Mueller et al. (1999) found no difference in nest success between areas treated with *Amdro*^{TM} and areas not treated.

In my study, it appeared that more bobwhite chicks survived to fledgling age in the non-treated areas of the refuge in 2014, and that treatment did not improve sample mean insect biomass or numbers in 2014 or 2015 (Chapter II). These results are not consistent with those of Mueller et al. (1999), who observed bobwhite brood survival to 3 weeks was higher for broods which hatched in treated areas. My results are consistent with the results of Morrow et al. (2015), which found no difference in insect abundance existed between treated and non-treated areas of the APCNWR. However, Morrow et al. (2015) did observe higher insect abundance in treated areas of several other sites studied, and Allen et al. (2001) found greater insect abundance in areas treated for RIFA on their study site. Morrow et al. (2015) also observed that Attwater's prairie-chicken brood survival more than doubled for broods spending all their time in RIFA treated areas compared to broods that never used treated areas. It is possible that my results are related to factors other than those which I researched such as predator abundance, vegetative succession, and/or rainfall differences between the treated and non-treated areas of the APCNWR in 2014 and 2015.

The refuge received heavy rains in the month of May 2014 (www.ncdc.noaa.gov), which likely flooded many northern bobwhite first nesting attempts. It was noted that much of the non-treated areas consisted of coarse sand ecological site and that much of the treated areas consisted of claypan prairie and loamy prairie (Fig. 1.4, Chapter I). It is possible that sandy soils allowed for better drainage of rainfall and, thus, better first-nest survival, which typically result in larger broods than renesting attempts (N. Silvy, personal communication), during May 2014 in the non-treated areas as compared to treated areas. In addition, I saw fewer hens with broods in treated areas; however, this trend was not significant. It also is possible that other ecological site and associated vegetative composition differences between treated and non-treated areas influenced my results.

Unintended Captures

These unintended captures provided an opportunity to observe a number of small granivores inhabiting the APCNWR. Mourning doves were the most often-captured species by total number and per hour. This is likely due to the high abundance of mourning doves on the refuge as well as the similarity of diets/attraction to our bait between northern bobwhites and mourning doves. Several migratory species were only captured during the spring and summer months; such as the northern cardinal, red-winged blackbird, and white-crowned sparrow. Several captured species were unexpected, as they are typically known as insectivores. These included the dickcissel, upland sandpiper, and meadowlark. These birds may have been captured due to insects entering the traps, which could lead an insectivore to follow.

As total trapping hours were inconsistent between months, I calculated an overall rate of captures per hour for the top 7 most-captured species (Fig. 3.2). These data give a more accurate idea of how many of each species one could intend to capture in a given time than total raw captures data.

It is possible that the unintended capture of species other than northern bobwhites influenced the number of quail captured. All captured species were released as soon as possible; however, it is likely that distress exhibited by trapped animals spooked some bobwhites away from the traps. As well, it is likely that trapped bobwhites prevented other species from entering the traps at times.

CHAPTER IV

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

The northern bobwhite (*Colinus virginianus*) is an ecologically and economically important game bird species that is experiencing a decline. While large-scale treatment of ants with *Extinguish Plus*^{TM} on the Attwater Prairie Chicken National Wildlife Refuge (APCNWR) was initiated as a management action for the critically endangered Attwater's prairie-chicken (*Tympanuchus cupido attwateri*), it provided me an opportunity to evaluate the effectiveness of large-scale red imported fire ant (RIFA, *Solenopsis invicta*) reduction on northern bobwhite (*Colinus virginianus*) abundance.

Based on my study, the following conclusions were drawn:

1. Treatment with *Extinguish Plus*^{TM} reduced RIFA abundance in 2014 and 2015.
2. Treatment with *Extinguish Plus*^{TM} did not improve food invertebrate abundance in 2014 or 2015 at random sampling locations.
3. Because of extremely small sample size, I could not conclude if treatment with *Extinguish Plus*^{TM} improved northern bobwhite nest success in 2014 or 2015.
4. Treatment with *Extinguish Plus*^{TM} did not improve the percent of female northern bobwhites with broods or the mean brood size per female in 2014.

Based on the results of my 13-month study, I conclude the use of *Extinguish Plus*^{TM} to reduce RIFA did not lead to higher invertebrate or northern bobwhite abundance. It is possible that my results are related to factors other than those which I researched such as predator abundance, vegetative succession, and/or rainfall differences between the treated and non-treated areas of the APCNWR in 2014 and 2015.

Additional research and/or a longer-termed study of the effects of large-scale RIFA treatment on northern bobwhites would be beneficial to either strengthen or oppose the conclusions of my study. Unlike other proposed remedies to the quail decline (habitat restoration, etc.), aerial RIFA treatment is relatively inexpensive and easy to implement. If such treatment proves effective at increasing bobwhite abundance, these methods will provide wildlife managers a tool which would increase their chances of slowing, stopping, or reversing the quail decline.

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